

H. Sheet Steel Fatigue Characteristics

Principal Investigator: Gene Cowie

Auto/Steel Partnership

2000 Town Center, Suite 320, Southfield, MI 48075-1123

(248) 945-4779; fax: (248) 356-8511; e-mail: gcowie@a-sp.org

Chairman: John Bonnen, Ph.D.

Ford Motor Company, Ford Research Laboratory

20000 Rotunda Drive, Dearborn, MI 48121-2053

(313) 322-9127; fax: (313) 390-0514; e-mail: jbonnen@ford.com

Technology Area Development Manager: Joseph A. Carpenter

(202) 586-1022; fax: (202) 586-1600; e-mail: joseph.carpenter@ee.doe.gov

Field Technical Manager: Philip S. Sklad

(865) 574-5069; fax: (865) 576-4963; e-mail: skladps@ornl.gov

Contractor: U.S. Automotive Materials Partnership

Contract No.: FC26-02OR22910

Objective

- Compile the test data generated in the previous phases of the program into a user-friendly database so that it can be used in all phases of design and structural analysis of sheet-steel vehicle bodies.
- Investigate the fatigue life of joints formed by spot welding, adhesive bonding, and weld bonding (a combination of welding and adhesive bonding).
- Explore the parameters for testing metal inert gas (MIG) and laser-welded joints.

Approach

- Investigate the fatigue characteristics of spot welding, a fusion process in which the metal being joined is melted and resolidified, forming an alloy with a distinctly different microstructure than that of the metals that are joined. In addition, the weld nugget, or button, may contain discontinuities, which can become sites at which fatigue cracks form. The amount and type of discontinuities are affected to a considerable extent by the welding process. The microstructures of the joined metals are also refined in the area adjacent to the weld, which is known as the heat affected zone (HAZ).
- Investigate the fatigue characteristics of adhesive bonding, which introduces an entirely different material into the load path. The adhesive must adhere to the metals being joined and resist fatigue failure at the areas of contact and within itself.
- Investigate the fatigue characteristics of weld bonding, a combination of adhesive bonding and spot welding.
- Investigate the previously unknown, or at best little known, factors that are expected to improve durability and facilitate modeling and simulation.
- Investigate the fatigue characteristics of MIG welding, a fusion process, which also forms alloy microstructures different from the metals being joined.

Accomplishments

- Defined parameters of the sheet-steel fatigue database and engaged a contractor to perform the work. The database has been constructed and has undergone several evaluations by team members. Work is expected to be complete by the end of 2004.
- Selected 27 combinations of steel grade and coating for joint fatigue testing. Of the combinations, 22 were spot welded, and all are completed. Two of the combinations were weld bonded, and both have been completed. Three of the combinations were bonded, with all three in process.
- Contacted several consultants, invited them to present proposals for fatigue testing MIG welds, and selected one to develop a test program.

Future Direction

- Analyze the data from spot weld fatigue tests (882 specimens).
- Verify the accuracy of the information and determine the fatigue performance of the advanced high-strength steels tested.
- Ensure that the information will be made available on the Auto/Steel Partnership Web site and in published form through SAE.
- Begin fatigue testing of MIG welds.

Introduction

In the era when vehicle mass was not a drawback and, in fact, was sometimes considered an advantage, the primary concern in body design was rigidity. More recently, the need to reduce body mass to comply with mandated corporate average fuel economy (CAFE) while improving the levels of occupant protection in a crash or rollover, caused design engineers to reexamine design procedures and materials. High-strength steels, judiciously selected and applied, emerged as potential low-cost (compared with aluminum and plastics), reliable materials for meeting these mandates. As structural components are optimized and thinner gauge, higher strength materials are assessed, fatigue life of the component and the areas where loads are transferred become considerations. To assess the performance of a component in the design phase, the fatigue characteristics of the base material and the areas where loads are transferred must be known. This project has completed a significant amount of testing of various grades of steel and is currently addressing joining methods most commonly used in vehicle bodies made from sheet steel.

welds, but there remains a need for a joint effort to evaluate the fatigue characteristics of welded and weld-bonded joints. Because spot welding is by far the most common welding process used in automotive steel bodies, initial efforts focused on this process.

The effort began in the 2002 fiscal year with presentations by key researchers on the current state of the work at DaimlerChrysler Corporation, Ford Motor Company, and General Motors Corporation. Based on these presentations, the Sheet Steel Fatigue Project Team was able to develop parameters for a test program that would produce results beneficial to all three companies. Early in the planning, the Auto/Steel Partnership (A/SP) Joining Technologies Team was consulted, and it was agreed that the Joining Technologies Team would prepare the samples to be tested. This interaction ensured that the samples would be joined using procedures that were properly controlled and in adherence to the best current practices in sheet metal joining.

Discussion

The three participating auto companies have been investigating the fatigue characteristics of spot

The following test parameters were developed and agreed on in the planning stage:

1. There will be two modes of testing: tensile shear (Figure 1) and coach peel (Figure 2).
2. Weld fatigue performance is independent of metal thickness for mild steels and high-strength low-alloy (HSLA) grades; therefore, tests on these grades will utilize only one metal thickness (1.6 mm).
3. Because no such data are yet available for advanced high-strength steel (HSS), several grades in this class will be tested at two thicknesses (1.6 mm and 0.7 mm).
4. Testing will be done at two R ratios: 0.1 and 0.3. R is the stress ratio, defined as the ratio of the minimum stress to the maximum stress in the test cycle. Maximum and minimum values are algebraic, with tension designated as positive and compression negative.
5. Eight steel grades were originally selected for testing. The number was subsequently increased to 11.

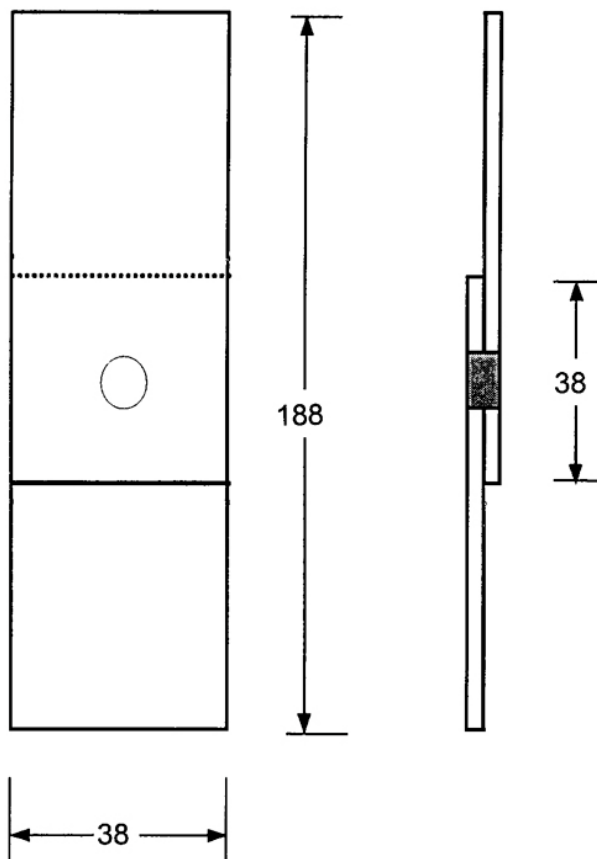


Figure 1. Lap shear test specimen.

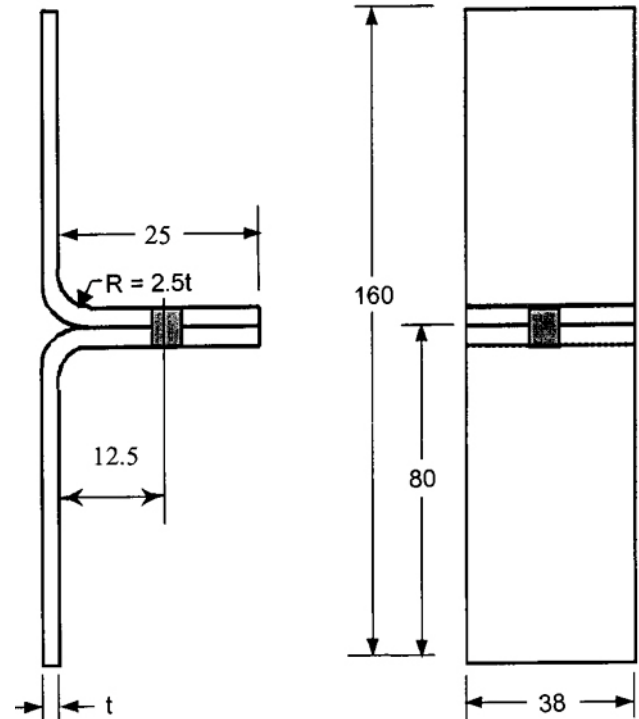


Figure 2. Coach peel test specimen.

6. Testing was originally planned for spot-welded and weld-bonded joints. Several tests on joints that were bonded only were added.

The team prepared a statement of work and sent it to nine testing laboratories known to have capabilities in this type of testing and invited them to submit proposals.

- The University of Alabama, Tuscaloosa, Alabama
- Colorado School of Mines, Advanced Steel Processing and Products Research Center, Golden, Colorado
- University of Dayton Research Institute—Dayton, Ohio
- University of Missouri—Columbia, Missouri
- University of Nevada—Reno, Nevada
- University of South Carolina—Columbia, South Carolina
- University of Toledo—Toledo, Ohio
- University of Waterloo—Waterloo, Ontario, Canada
- Westmoreland Mechanical Testing and Research, Inc.—Youngstown, Pennsylvania

All nine responded with acceptable proposals. The project team reviewed the proposals based on technical competency, qualifications of key personnel, demonstrated experience, understanding of the project requirements and price. Two were selected to perform the work: The University of Missouri in Columbia, Missouri, and Westmoreland Mechanical Testing and Research, Inc., in Youngstown, Pennsylvania.

As the testing progressed, and results were analyzed, the following tests were added for comparison purposes.

1. Testing at specified R ratios means that the maximum and minimum loads are constant throughout the test. This process is valuable for establishing baseline data. However, in the real world, loads can be expected to vary. For this reason, two sets of spectrum loading tests, run at predetermined load variations, were scheduled.
2. Two tests are in progress on samples with a different welding schedule that produced a smaller weld button.

3. Three tests were scheduled with samples joined by adhesive bonding only.
4. At the request of the Joining Technologies Team, three tests were scheduled using wide samples (125 mm vs the standard 38 mm). The wider samples minimize twisting of the weld under load.

Conclusions

Preliminary analysis of results received to date indicates that the fatigue performance of a spot weld is independent of the materials being welded. This finding supports the initial understanding that the melting and resolidifying processes (see Approach) form new alloys and make the properties and coating of the material(s) being joined and the welding parameters, insignificant contributors to fatigue performance. This conclusion will be verified or negated when the analysis of the work is completed during the next fiscal year.